Case Studies – Automotive Sector

Experiences and Thoughts About Life Cycle Assessment in the Automotive Industry in Japan

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Abstract. Experiences with Life Cycle Assessment (LCA) in the Japanese Automotive Industry and the author's thoughts on how to apply LCA for automobiles are described. In this paper, LCA applications are categorized into three types:

1. LCA that is strictly based on ISO 14040 series standards → In Japan, this type of LCA studies is used commonly by industry-wide or nation-wide research work,
2. LCA that is somehow not consistent with the ISO standards → This type is internally utilized by individual business companies for the purpose of development of environmentally conscious products with discussions about their own subjective judgement and choices, and
3. LCA that is completely streamlined in regard to the ISO standards → This type is limited to internal improvement activities for each process or shop in a factory, based on Life Cycle considerations.

The idea of the above mentioned categorization and distinctions of LCA applications may also be useful for assembly-based industries other than the automotive industry.

Keywords: Automotive industry; ISO standards; LCA in the Japanese automotive industry

Introduction

LCA, like other engineering tools utilized in industry sectors, is based on science. Even though LCA has scientific tastes and smells, there are some LCA specific features. **First**, a wide variety of science fields involved in LCA, such as resources, human health, meteorology, chemical reactions, biology and so on. In addition to that, science is always on the way to new discoveries and further evolution, thus is endless. **Second**, the time span covered by LCA is very long due to the aim to contribute to 'Sustainable Development', thus is infinite. **Third**, it tries to cover issues from the global to the local scale; in other words, from global change to damages on DNA.

On the other hand, tools like VA (Value Analysis) and DFA (Design for Assembly) employ fairly simple principles of science and mathematics. Furthermore, we can obtain actual results about the functionality of these tools. Therefore, we can validate the effectiveness of these tools by reviewing results derived from evaluations, which enables us to refine the methods in detail.

The differences between LCA and the other tools may lead engineers to mess, and 'so what' situations, and efforts in vain. We have to take these situations into account when we try to implement LCA as an engineering tool for product development.

1 LCA and Automobiles: LCA that is strictly based on ISO 14040 series standards

What a convenient product an automobile is!

Products or services that provide convenience always enlarge entropy, and they increase environmental loads on the earth, or the eco-system. In this sense, automobiles are bad for the environment.

People in the LCA society, as well as the general public, tend to pay too much attention to automobiles when they discuss environmental issues, while they often forget about human activities and the existence of human beings itself. This fact has led the Japanese automotive industry to organize joint activities or cooperative projects on LCA, however, there still exists competitiveness in the environmental field.

JAMA, Japan Automobiles Manufacturers Association, has organized an LCA working group (WG 3) under its Committee on Environment since 1994. The WG 3 has investigated similar areas such as those of joint LCA activities among European automotive manufacturers and AAMA, the Big Three. Tasks assigned to the JAMA WG 3 are to establish a common methodology for the industry as well as an LCI database for average Japanese automobiles. Since the ISO 14040 ff standardization process has taken place parallel to WG 3, the methodology referred to by JAMA WG 3 was mainly according to ISO. The WG 3 has reported its outcomes to some academic societies worldwide, e.g EcoBalance Conference 1996, SAE Total Life Cycle Conferences 1997 and 1998 [1,2,3]. A further publication is planned for EcoBalance Conference 2000 [4]. It is very important for the industry sectors to fully understand ISO standards as a basis for any research work and studies applying Life Cycle considerations.

Although JAMA activities have been encouraged and have produced many unique and useful outputs, ISUZU (my employer) itself could do nothing but take a look at reports and information from JAMA; so the information have been brought to some departments of ISUZU. LCI studies on ISUZU vehicles (**Fig. 1** and **2**) using JAMA software 'LCA 96' made us simply say 'that's it! and 'so what?' Many col-

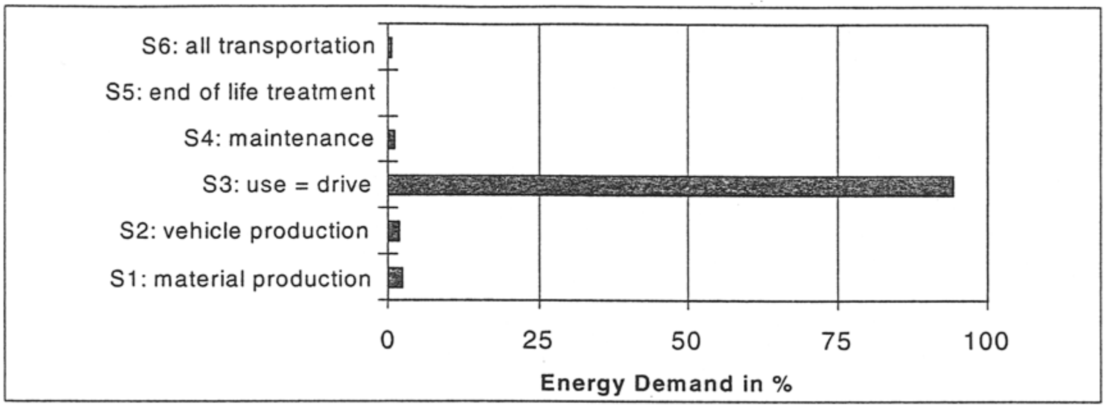

Fig. 1: Distribution of the total energy demand of a 4-ton truck

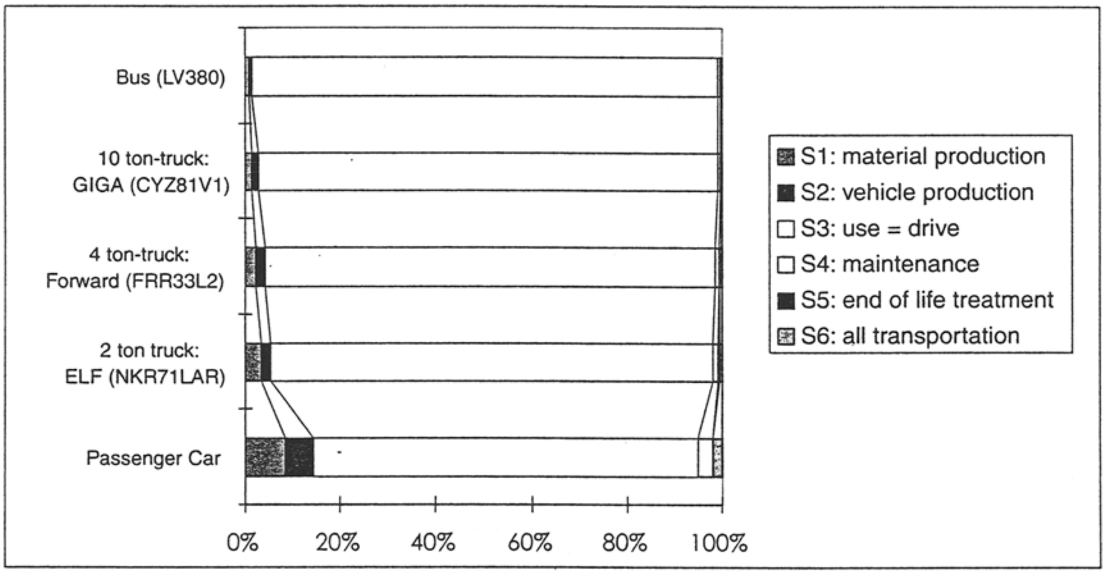

Fig. 2: Distribution of the total energy demand of several vehicles

leagues of mine told me 'you just quantify what I have in mind'. One reason for this comment is that JAMA software has only energy consumption and CO_2 emission as data categories. However, there must be some other essential reasons that cause this problem in applying LCA.

Similar results or experiences may be common among a group of people who are in charge of or are interested in LCA. The major problem or weak point of studies like these examples are that the conclusions are too general, thus the companies may have troubles in applying LCA to their own improvements in product development or decision making.

LCA research activities among the automotive industry have two objectives, politics and engineering. ISO 14000 series may cause impacts on the global business. From the political viewpoint, LCA studies are simply performed to understand ISO standards and to be prepared for business impacts or affects that may or may not occur and are even unknown. Another reason for the trouble with the LCA applications may be the fact that ISUZU has paid too much attention to the political issues, but less to the engineering aspects that should have been focused.

2 LCA or LCI Studies at ISUZU

This section relates to LCA that is somehow not consistent with the ISO standards and is applied to the development of environmentally conscious products.

2.1 Material selection

A case study on Propeller Shaft materials is one example that can be applied for material selection and product design. This study was performed 1990 through 1991 at ISUZU. The conventional material for the Propeller Shaft was a steel pipe with 540 MPa of tensile strength. Other alternative materials under discussion at ISUZU were high strength steel with 735 MPa tensile strength, aluminum alloy, and FRP (Glass and Carbon Fiber Reinforced Plastics).

Assumptions are summarized in **Table 1**. Calculated results are shown in **Table 2**. The high strength steel pipe (STAM735) showed no demerits, thus margins of merits were not so large. Technological development on welding processes was needed in order to keep maximum fatigue strength at welded areas on both ends of the Propeller Shaft. Since the completion of the development was achieved, STAM 735 high strength steel

Table 1: Conditions and assumptions

	Steel (former)	Steel (current)	Aluminum	FRP*
Material code (JIS or ISO)	STAM540H	STAM735H	modified 6061-T8	EP-(CF+GF)70
Tensile strength (MPa)	540	735	365	400
Specific gravity	7.85	7.85	2.91	1.85
Weight of the part (kg)	20.2	17.0	13.7	6.2
Energy used for material production (MJ/kg)	25.3	26.8	233	100
Energy used for part production (MJ/kg)	28.5	21.0	63	100
Weight reduction (kg)	0	-3.2	-6.5	-14.0
Saving of fuel consumption (litter/kg) (due to weight reduction)	0	1.76		
Reduction of exhaust gas emissions (per kg) (due to weight reduction)	0	-21 kg-CO_2 -51 g-NO_x -172 g-CO -26 g-SO_x		
Recyclability (%)	100	100	100	0

* Glass and Carbon Fiber Reinforced Plastics

Table 2: LCI results for propeller shaft, total distance = 450,000 km (Diesel fuel has 38.5 MJ/litter)

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Tensile strength (MPa)	540	735	365	400
Specific gravity	7.85	7.85	2.91	1.85
Weight of the part (kg)	20.2	17.0	13.7	6.2
Weight reduction (kg)	0	-3.2	-6.5	-14.0
1) Saving of energy for material production (MJ)	0	-55	+2681	+109
2) Saving of energy for part production (MJ)	0	-63	+246	-467
3) Saving of energy for operation (MJ)	0	-217	-440	-949
4) Recovered energy through recycling (MJ)	-329	-277	-2413	0
Total energy saved = 1) + 2) + 3) + 4) (MJ) (recovered not counted = 1)+2)+3))	-329 (0)	-722 (-445)	+72 (+2485)	-1307
Total reduction of exhaust gas emissions for 450,000 km of operation	0	-201 kg-CO_2 -490 g-NO_x -1651 g-CO -250 g-SO_x	-410 kg- CO_2 -1550 g-NO_x -3354 g-CO -507 g-SO_x	-882 kg- CO_2 -2142 g-NO_x -7224 g-CO -1092 g-SO_x
Solid waste at the end of life (kg)	0	0	0	6.2 (it is hard to separate FRP)

* Glass and Carbon Fiber Reinforced Plastics

has been employed. Aluminum alloy consumes much energy in material processing that would not recover energy by improved fuel consumption. FRP was the best material in terms of energy saving, but it would become waste at its end of life.

2.2 Design improvement

ISUZU has introduced DFA (Design for Assembly) and DFM (Design for Manufacturing) software developed by BDI (Boothroyd Dewhurst, Inc.) about ten years ago. Recently, DFE (Design for Environment) software was marketed, and ISUZU has introduced the DFE software because data obtained by DFA and DFM can be used in DFE analysis, which means human resources can be saved in input operations.

The previous study only focuses on the specific component, Propeller Shaft, out from the whole vehicle. The same concept has been applied to this trial example, and only IP (Instrument Panel) was evaluated.

This trial was performed in the very early stage of development. First, DFA analysis was performed, then DFE. Table 3 presents how IP (Instrument Panel) has improved its efficiency in the assembly and disassembly stages and in reducing environmental loads.

MET points, where M, E, and T represent Material cycles, Engery use, and Toxic emissions, were derived using methodology that is installed in the software by BDI and TNO [5]. There may be many assumptions and subjectivity, and the MET points will have no meaning once they are disclosed outside of ISUZU. It is ISUZU design people, based on suggestions by LCA engineers, who makes decisions on how IP should be designed. All responsibility is on ISUZU engineering people with applying ISUZU's own subjective judgement.

3 Streamlined LCA

This section relates to LCA that is completely streamlined in regard to the ISO standards and is limited to internal improvements based on Life Cycle considerations.

This type of LCA study, no longer consistent with LCA based on ISO 14040, aims at the application of Life Cycle considerations in addition to the conventional QCD (Quality, Costs, and Delivery). The scope of the study is very limited to where

Table 3: Example of DFE (Design for Environment) in addition to DFA (Design for Assembly) analysis

Item to be calculated and evaluated	Instrument Panel Design		
	former model	new model, current, original design	new model, current, after improvement
Weight of part	11.7 kg	11.7 kg	11.7 kg
DFA index	3.8	9 (improved by 55%)	9 (improved by 82%)
DFA: sum of numbers of parts and assembly processes	176	156 (improved by 11%)	141 (improved by 20%)
DFA: assembly time (second)	1215	977 (improved by 20%)	840 (improved by 31%)
DFE: total environmental load index *	5986	5560 (improved by 7%)	5538 (improved by 8%)
DFE: disassembly time (second)	1376	827 (improved by 40%)	601 (improved by 56%)

*No environmental load is included in the DFE-Index since the weights are about the same among the three alternatives.
*The DFE-Index is just an aggregated score of total environmental impacts that include subjectivity.

Table 4: Summary of EcoDS evaluation results, comparing alternative operations of ISUZU paint shops

Alternative	Cost		Environmental Impact			
	capital	operating	energy usage	air emissions	liquid discharge	solid waste
P2 shop for RV, and P3 for CV, operation until October 1998	0	A*	VERY HIGH	VERY HIGH	HIGH	VERY HIGH
All RV and CV are painted in P3, current operation from October 1998	B*	C*	MEDIUM	HIGH	MEDIUM	MEDIUM

EcoDS can be accessed via the internet home page of Vanderbilt University (http://shogun.vuse.vanderbilt.edu/).
*cost information cannot be disclosed, but the Break Even Point occurred early in the 2nd year, and 5.9 billion yen can be saved after 4 years.

a company can change by itself based on its own subjective judgement and responsibility. It could be called 'first hand, quick LCA'. Therefore, studies like process improvements are appropriate for this type of LCA. ISUZU studied operational changes performed in paint shops in Fujisawa Plant, and it used this type of streamlined LCA.

Up until fall 1998, ISUZU Fujisawa Plant had two paint shops, the one for RVs (Recreation Vehicles) and the other for CVs (Commercial Vehicles or Trucks). A plan to merge into one paint shop (the other paint shop to be shutdown) was proposed and many investigations were performed by engineering departments. Of course, new process technologies and new paint materials, such as quick cure type ED and other paints, must be developed. Among the investigations, streamlined LCA was studied together with investment and operation costs analyses.

Table 4 summarizes the results. The scope of the study was just common portion of conventional and new (merge into one and the other shutdown) operations. Prior to the study, various levels and various departments had questionnaires exploring their value for many environmental aspects and economical decisions. The ISUZU's value system to transform environmental importance into costs has been analyzed and evaluated.

4 Conclusions

It is no question about an opinion like 'ISO LCA is the most important for people who are going to use LCA'. We must understand what is written in ISO 14040 series. Especially, the most important thing for us is to read and understand the ISO standards, and to properly prepare reports according to each application strictly following the ISO rules and recommendations. But, when we think about applications of LCA, the form of LCA studies does not need to be fully consistent with ISO standards. According to the applications, their form may change widely, from strictly ISO-based to streamlined LCA.

ISO-based LCA studies are essential tools for all people in charge of LCA. This ISO LCA must be commonly used by inter-company and inter-industry activities as well as by nation-wide research work. Japan's national project on LCA led by MITI and JAMA LCA project falls into this category.

LCA that is not strictly consistent with the ISO standards can be internally utilized by individual business companies aiming at the implementation of LCA for their development of environmentally conscious products. This category of LCA includes subjective judgement and choices, and careful disclosure should be considered. Eco-Design and DFE may be applications of LCA that fall into this category.

Completely streamlined LCA is limited to internal improvement activities for each process or shop in a factory based on Life Cycle considerations. Environmental issues can be discussed with QCD at the same table. Data from PRTR law in Japan and EPE, upcoming ISO 14031, may belong to studies of this category. Support for decision making is the most important output from this type of LCA studies, thus data regarding environmental loads themselves are less important. Therefore, value systems must be developed within each organization. Disclosure of the study results must be considered very carefully.

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